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DIGESTIBILITY OF SOME ANIMAL FATS.

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CONTENTS.

Page.
Introduction 1
Nature of the diet 2
Experimental methods 4
Digestion experiments—Lard, beef fat, mutton fat, butter 5
General discussion 20

INTRODUCTION.

Notwithstanding the fact that fats are ordinarily one of the principal sources of energy in the diet and are two and one-fourth times as effective for this purpose as either protein or carbohydrates, their use in the diet has received less attention by investigators, and is consequently less perfectly understood than that of other nutrients.

It has generally been taken for granted that when eaten in favorable combinations fats are thoroughly assimilated and that the different kinds do not vary enough in this respect to affect materially the amount of energy which the body derives from them. The recorded experimental data, however, are not conclusive on this point. Experimental data are also very limited on another point which is a matter of particular interest at the present time, when the increased demand for culinary and table fats tends to bring into the market kinds which have hitherto been used little if at all, namely, the relation of melting point to thoroughness of digestion, particularly with respect to fats of high melting point.

It is true that many digestion experiments have been carried on with food materials such as milk, cheese, meat, etc., which contain much fat, but relatively few dealing directly with culinary and table fats have been reported and only a small proportion of these have been made under comparable conditions, and while it is also true that the melting point of fats has been very generally and accurately deter-

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NOTE.—This bulletin records studies of the digestibility and melting point of lard, beef fat, mutton fat, and butter, and is primarily of interest to students and investigators of food problems.

mined it has not been possible to correlate melting point with digestibility in an exact way on the basis of experiments hitherto made.

The practical importance of further investigations on the subject is indicated by the fact that the common domestic practices in the use of fats, as of other food materials, is at present based very largely on empirical knowledge, and quality in the resultant product depends more upon experience and acquired skill than it does upon knowledge of the physical and chemical properties of the ingredients used and of their relation to the desired object. Yet it is obvious that the whole matter is one which can not be definitely understood, standardized, and controlled unless such knowledge is available. A full understanding of the materials, of the nature of household methods of handling them, and of the resulting effects is necessary as a basis for real economy as well as for more rational and satisfactory use of foodstuffs. The right use of food materials must be governed also by a knowledge of their digestibility and their value as sources of energy available to the body. Neither can one overlook the modifications which are due to the combination of ingredients into foods and to the combination of foods to form meals.

It seemed desirable, therefore, from both the scientific and the practical standpoint to study the digestibility of the more common culinary and table fats prepared in a comparable manner and incorporated in a uniform basal ration. It was with this idea in mind that the digestion experiments with four of the more common animal fats reported in this bulletin were undertaken. These experiments form part of an extended study of the food value and household uses of animal and vegetable fats of different sorts, having to do with (1) the thoroughness of digestion of the fats, (2) the specific dynamic effect of a diet rich in fats of different kinds, (3) the relation of the available (net) to the total (gross) energy values of fats, and (4) the relation of domestic ways of using fat to the quality of foods.

NATURE OF THE DIET.

The experiments here reported were made with beef tallow, mutton tallow, lard, and butter, which were purchased in the open market. The butter was a good commercial grade and was used as purchased.

The beef, mutton, and pork fats were kidney fats. A fairly large quantity of each was rendered in the laboratory in order to provide uniform material for use in each series of experiments. The fat was cut into small pieces, freed from any noticeable muscular tissue, and finely ground in a meat cutter such as is used in the home. It was then rendered in a double boiler, when it was found that the fat separated readily from the inclosing tissues (the temperature during rendering did not quite reach 100° C.). The fat was finally strained through medium fine huckaback and heated, but not much above the temperature of boiling water, to drive off surplus water and thus improve its keeping qualities. Care was exercised not to heat the fat too high.[1] Judged by the usual household tests, the resulting product in all cases was most satisfactory, being of good color and flavor and free from sediment.

As sufficiently large quantities of the fats to be studied could not be consumed in the natural state, a method of preparing them for eating was sought. The most satisfactory one found was to incorporate the fat in a blanc mange or cornstarch pudding. This was best prepared by cooking skim milk, to which sugar and a considerable quantity of a caramel solution had been added, in an ordinary double boiler, at as high a temperature as could be reached (nearly 100° C.). A mixture of commercial cornstarch and the fat under consideration was then slowly added with continuous stirring, and the heating continued until the starch was well cooked. Skim milk was used to avoid the presence of any considerable amount of butter fat, which would interfere with the study of the particular fat under consideration. The caramel solution was designed to mask the presence of the large quantity of fat by supplying a characteristic and uniform color and flavor to the blanc mange, for a distinctly fatty flavor is disagreeable to many persons and, furthermore, experience has shown that it is highly desirable in making experiments of this character to avoid as far as possible any psychic effects, which in some instances may play an important rôle in the digestion of food. It was usually necessary to add such a large quantity of the caramel solution that the blanc mange had a slightly bitter taste, but this feature was readily overcome by the addition after cooling of a little vanilla extract. The blanc mange prepared in this way resembled a common household dessert, except that it was not noticeably sweet. It has been used to a considerable extent and with good results in this laboratory as a medium for supplying special foodstuffs in experimental diets. The question of the nature of the food was not discussed with the subjects and the masking of the fat was so complete that none of them appeared at any time to notice differences in the flavor of the blanc mange; at least no comments on the matter were made.

In studying the digestibility of a single food, experience has shown that it is desirable to incorporate it in a very simple mixed diet, since the ordinary individual is so accustomed to a mixed diet, that, no matter how palatable a single food may be at first, it eventually becomes distasteful. Consequently, in these experiments it was decided to use, in addition to the blanc mange containing the fat under consideration, a very simple mixed basal diet composed of a commercial wheat biscuit, fruit, and tea or coffee, with a little sugar if the subject desired.

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[1] It has been noted in the Biochemic Laboratory of the Bureau of Animal Industry that the keeping qualities of fats which have been subjected to elevated temperatures have apparently been lessened.

EXPERIMENTAL METHODS.

Each test period included three days, or nine meals, a period long enough for the purpose, but, as shown by experience, not of sufficient duration to make the diet distasteful. In order that the subject should experience no sense of monotony, the ration in question was served for only one test period per week, followed by a rest period of four days, in which the subject lived as usual on a mixed diet. Furthermore, the tests with fat were alternated with tests of an entirely different sort of diet, so that the same sort of food was not eaten oftener than on alternate weeks.

The subjects changed from time to time according to circumstances, but, since their ages, occupations, and modes of living did not vary materially, the results obtained for the different fats are believed to be directly comparable. The men were between 20 and 30 years of age, students in medical and dental schools, and sufficiently informed in physiological questions to appreciate the importance of accuracy in carrying out such directions as were given them. They were urged to observe special care in the collection of feces, for accuracy in this particular is essential in determining the amount of food retained and assimilated by the body. They were asked to supply data as to their physical condition, both before and after, as well as during the time occupied by the experimental periods, but since all remained in normal physical condition none of the individual reports are incorporated in this paper.

The amounts and kinds of food eaten during each three-day experimental period were recorded as well as the total quantity of feces, and samples of both food and feces were analyzed to determine the quantities of protein, fat, carbohydrate, and mineral matter retained and assimilated by the body. Since sufficient quantities of blanc mange were prepared to serve for an entire test period, only one analysis of the blanc mange was necessary. Only occasional analyses of the wheat biscuit were made, as it was found to be of very uniform composition.

In order to facilitate the identification of the feces of a test period, charcoal,[1] which imparts a dark color to the feces, was taken with the first meal of the test period and with the first meal following the test period. The feces first showing a dark color and all excreted until the color imparted by the charcoal was again noticed were retained for analytical purposes. The feces were freed from water by drying at 95° C., and analysis was made on the dry basis. The urine was not collected and no determinations of the heats of combustion of food or feces were made, since factors have been reported by means of which the available energy value can be computed with reasonable accuracy. It was not considered necessary to determine variations in the body weight of the subjects, as the purpose of the investigations was to ascertain the availability to the body of the particular fats in question rather than to supply a diet of sufficient nutritive and energy value to meet the body needs. All analytical determinations were made according to the methods outlined by the Association of Official Agricultural Chemists.[1] The resultant data only are included in the report of the experiments which follow. The dates of the individual tests and all the detailed data not essential in interpreting the results are on file at the Department of Agriculture, where they may be consulted.

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[1] U. S. Dept. Agr., Office Expt. Stas. Bul. 143 (1904), pp. 66–77.

DIGESTION EXPERIMENTS.

LARD.

Pork fat is utilized for food in a variety of forms, the most common of which are bacon, salt and fresh fat pork, and lard. Lard is used principally for frying and for shortening foods, though sometimes flavored with sweet herbs and spread on bread, like "drippings."

In view of the wide use of lard as a food material, it is noteworthy that no very extensive study of its digestibility has been found on record.

Rubner [2] determined the digestibility of bacon, making two experiments in which 100 and 200 grams were eaten daily, and found an average digestibility of 87 per cent. This obviously is not a true value, since he reports that the feces contained small pieces of bacon which had not been disintegrated.

Work concerning fat resorption by man and animals in pathological conditions was carried out by Adler.[3] His study of pork fat seemed to warrant the conclusion that in pathological conditions cooked bacon was more readily absorbed than raw bacon.

Grindley et al.,[4] in a study of the influence of different methods of cooking upon the thoroughness and ease of digestion of meat, have reported four experiments with fat fresh pork, the fat of which was 99.4 per cent digested.

In a number of tests comparing the digestibility of lard with that of some other animal fats, Levites [5] found that lard was somewhat less thoroughly assimilated than butter and beef fat, from which he concluded that lard possesses a laxative property.

Moore,[6] in conducting experiments to determine the digestibility of some of the more common fats, found that about 97 per cent of cooked lard was digested by mice and that raw lard was from 74 to 89 per cent digested by guinea pigs.

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[1] U. S. Dept. Agr., Bur. Chem. Bul. 107 (1912).

[2] Ztschr. Biol., 15 (1879), No. 1, pp. 170-174.

[3] Ztschr. Klin. Med., 66 (1908), No. 3-4, pp. 302-316.

[4] U. S. Dept. Agr., Office Expt. Stas. Bul. 193 (1907), p. 41.

[5] Ztschr. Physiol. Chem., 49 (1906), No. 2-3, pp. 273-285.

[6] Arkansas Sta. Bul. 78 (1903), pp. 33-41.

To secure data regarding the thoroughness of digestion of lard by normal individuals living under uniform conditions, nine tests were made in this laboratory and six different subjects were used. The experiments were performed in different seasons of the year, because of the belief sometimes expressed that fats are better utilized in colder than in warmer weather. The results are recorded in the following tables:

Data of digestion experiments with lard in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 38, subject J. C.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blanc mange containing lard	1,765.0	1,086.6	39.9	254.1	375.9	8.5
Wheat biscuit	186.5	15.9	25.0	2.1	140.5	3.0
Fruit	1,471.5	1,278.7	11.8	2.9	170.7	7.4
Sugar	168.0				168.0	
Total food consumed	3,591.0	2,381.2	76.7	259.1	855.1	18.9
Feces	63.5		17.6	11.2	26.3	8.4
Amount utilized			59.1	247.9	828.8	10.5
Per cent utilized			77.1	95.7	96.9	55.6
Experiment No. 39, subject J. F.:						
Blanc mange containing lard	1,740.5	1,070.3	39.5	250.7	371.4	8.6
Wheat biscuit	194.0	16.5	26.0	2.2	146.2	3.1
Fruit	1,698.7	1,476.2	13.6	3.4	197.0	8.5
Sugar	51.7				51.7	
Total food consumed	3,684.9	2,563.0	79.1	256.3	766.3	20.2
Feces	86.0		21.1	13.1	41.5	10.3
Amount utilized			58.0	243.2	724.9	9.8
Per cent utilized			73.3	94.9	94.6	48.5
Experiment No. 44, subject J. C.:						
Blanc mange containing lard	1,752.5	947.6	40.1	218.9	532.9	13.0
Wheat biscuit	261.0	22.2	35.0	3.0	196.6	4.2
Fruit	1,029.5	894.6	8.2	2.1	119.4	5.2
Sugar	59.5				59.5	
Total food consumed	3,102.5	1,864.4	83.3	224.0	908.4	22.4
Feces	64.0		20.0	10.9	25.9	7.2
Amount utilized			63.3	213.1	882.5	15.2
Per cent utilized			76.0	95.1	97.1	67.9
Experiment No. 47, subject R. L. S.:						
Blanc mange containing lard	1,715.6	774.7	40.8	288.4	597.1	14.6
Wheat biscuit	493.3	41.9	66.2	5.6	371.7	7.9
Fruit	734.7	638.4	5.9	1.5	85.2	3.7
Sugar	70.7				70.7	
Total food consumed	3,014.3	1,455.0	112.9	295.5	1,124.7	26.2
Feces	81.0		25.0	13.8	33.3	8.9
Amount utilized			87.9	281.7	1,091.4	17.3
Per cent utilized			77.8	95.3	97.0	66.0
Experiment No. 48, subject I. D. B.:						
Blanc mange containing lard	1,717.9	777.2	40.8	288.8	596.2	14.9
Wheat biscuit	391.8	33.3	52.5	4.5	295.2	6.3
Fruit	1,158.6	1,006.8	9.3	2.3	134.4	5.8
Sugar	39.3				39.3	
Total food consumed	3,307.6	1,817.3	102.6	295.6	1,065.1	27.0
Feces	117.8		36.9	24.6	43.1	13.2
Amount utilized			65.7	271.0	1,022.0	13.8
Per cent utilized			64.0	91.7	96.0	51.1

Data of digestion experiments with lard in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Experiment No. 53, subject W. D.:						
Blanc mange containing lard	1,909.1	1,176.0	56.1	263.6	399.8	13.5
Wheat biscuit	418.3	35.6	56.1	4.8	315.2	6.7
Fruit	1,362.2	1,183.8	10.9	2.7	158.0	6.8
Sugar	....	....	....	....	....	....
Total food consumed	3,689.6	2,395.4	123.1	271.1	873.0	27.0
Feces	92.4	....	19.9	15.8	44.9	11.8
Amount utilized	....	....	103.2	255.3	828.1	15.1
Per cent utilized	....	....	83.8	94.2	94.9	55.9
Experiment No. 54, subject I. D. B.:						
Blanc mange containing lard	1,924.1	1,185.2	56.6	265.7	402.9	13.7
Wheat biscuit	578.1	49.1	77.5	6.6	435.6	9.3
Fruit	1,245.2	1,082.1	10.0	2.5	144.4	6.2
Sugar	97.3	....	....	....	97.3	....
Total food consumed	3,844.7	2,316.4	144.1	274.8	1,080.2	29.2
Feces	159.2	....	48.1	32.3	63.9	14.9
Amount utilized	....	....	96.0	242.5	1,016.3	14.3
Per cent utilized	....	....	66.6	88.2	94.0	49.0
Experiment No. 55, subject R. L. S.:						
Blanc mange containing lard	2,118.8	1,305.2	62.3	292.6	443.7	15.0
Wheat biscuit	637.1	54.2	85.4	7.3	480.0	10.2
Fruit	742.3	645.0	6.0	1.5	86.1	3.7
Sugar	54.0	....	....	....	54.0	....
Total food consumed	3,552.2	2,004.4	153.7	301.4	1,063.8	28.9
Feces	87.7	....	24.3	18.0	36.1	9.3
Amount utilized	....	....	129.4	283.4	1,027.7	19.6
Per cent utilized	....	....	84.2	94.0	96.6	67.8
Experiment No. 56, subject E. M.:						
Blanc mange containing lard	1,808.1	1,113.8	53.2	249.7	378.6	12.8
Wheat biscuit	465.0	39.5	62.4	5.3	350.4	7.4
Fruit	1,496.6	1,300.5	12.0	3.0	173.6	7.5
Sugar	110.3	....	....	....	110.3	....
Total food consumed	3,880.0	2,453.8	127.6	258.0	1,012.9	27.7
Feces	110.1	....	35.7	13.9	46.7	13.8
Amount utilized	....	....	91.7	244.1	966.2	13.9
Per cent utilized	....	....	72.0	94.6	95.4	50.2
Average food consumed per subject per day	1,172.8	713.0	37.2	90.2	324.1	8.4

Summary of digestion experiments with lard in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
38	J. C	77.1	95.7	96.9	55.6
39	J. F	73.3	94.9	94.6	48.5
44	J. C	76.0	95.1	97.1	67.9
47	R. L. S	77.8	95.3	97.0	66.0
48	I. D. B	64.0	91.7	96.0	51.1
53	W. D	83.8	94.2	94.9	55.9
54	I. D. B	66.6	88.2	94.0	49.0
55	R. L. S	84.2	94.0	96.6	67.8
56	E. M	72.0	94.6	95.4	50.2
	Average	75.0	93.7	95.8	56.9

It will be noted on reference to the table that in experiments Nos. 48 and 54, both with the same subject (I. D. B.), the percentage digestibility of fat is materially lower than the others and that this tends to lower the average. However, since there were apparently no abnormal conditions, these results have been included in obtaining the average. The digestibility of the fat content of the total diet, 93.7 per cent, should closely approximate the digestibility of lard, since over 97 per cent of the total fat consumed was lard.

The "digestibility" of fat is often a matter of popular discussion, and not infrequently the statement is made that "lard is indigestible." The term "indigestible" in the accurate sense implies that a large part of the food in question leaves the body unassimilated, though sometimes the expression is loosely used to explain a digestive disturbance resulting from eating the food. In these tests the fat was very thoroughly assimilated as compared with the other fats included in the investigation, so it was not indigestible in the sense that it failed to digest. No distress was experienced by the subjects, nor were any unusual circumstances observed, so in these experiments at least, the lard was not "indigestible" in the popular sense.

It is frequently noted that those who think they can not eat lard have no such feeling in regard to bacon, which is one of the very popular fat foods. Before the whole question can be settled, it is desirable to make tests with lard, bacon, and other fats, in which the fat is incorporated with the other ingredients of the diet of which it forms a part and subjected to a higher temperature (as in frying and baking) than was used to make the blanc mange in these experiments.

BEEF FAT.

Beef suet is used as a fat for sautéing and deep frying and in making suet puddings and dumplings, which are fairly common in the United States, though less so than in Great Britain, and for other culinary purposes. Rendered beef fat is not used as a table fat in this country to any great extent, though in Europe families of small means often eat so-called "drippings" on their bread in the place of butter.

Beef suet has a rather pronounced and characteristic flavor as well as a comparatively high melting point; to these properties may be attributed the fact that it is not a common table fat in the United States. Experience and experiments show that it is possible to remove much of the characteristic taste. One household method which is fairly successful is to mix milk with the suet when it is rendered, using half a cup of milk to a pound of suet. On straining and cooling practically all the milk solids are occluded and serve to change or mask the characteristic beef-fat flavor.

As was the case with lard, few reports of experiments on the digestibility of beef fat have been found.

Flurin[1] was interested in determining the relative digestibility of butter and beef tallow, which he regarded as typical animal fats. The average coefficients of digestibility were found to be 95.9 per cent and 92.8 per cent, respectively.

Levites[2] studied the relative digestibility of beef fat, lard, and butter, and found that butter and beef fat were both 96 per cent digested.

Grindley et al.,[2] in experiments to determine the thoroughness of digestion of various meats, found that the average digestibility of fat present in a shoulder of beef rich in fat was 97.3 per cent, but this coefficient may not be applicable to kidney fat. In an attempt to compare the digestibility of edible fats, using guinea pigs as subjects, Moore[2] found that the fat of raw beef suet was 73.7 per cent utilized.

In the work here reported the fat was incorporated in a blanc mange in the manner previously described. During the first three experiments the subjects ate large amounts, approximately 140 grams per day, but they reported a laxative effect from eating this quantity of fat. As this seemed to indicate that the limit of tolerance was being approached, smaller quantities of fat were eaten in the succeeding periods.

The results of the digestion experiments with beef fat contained in a simple mixed diet follow:

Data of digestion experiments with beef fat in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 61, subject W. D.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams*	*Grams.*
Blanc mange containing beef fat	2,255.5	1,134.5	45.1	412.8	649.6	13.5
Wheat biscuit	544.9	46.3	73.0	6.0	410.9	8.7
Fruit	1,354.0	1,176.6	10.8	2.7	157.1	6.8
Sugar	....	....	....	....	....	....
Total food consumed	4,154.4	2,357.4	128.9	421.5	1,217.6	29.0
Feces	80.5	....	17.5	23.8	31.2	8.0
Amount utilized	....	....	111.4	397.7	1,186.4	21.0
Per cent utilized	....	....	86.4	94.4	97.4	72.4
Experiment No. 62, subject E. M.:						
Blanc mange containing beef fat	2,486.0	1,250.5	49.7	454.9	716.0	14.9
Wheat biscuit	499.8	42.5	67.0	5.5	376.8	8.0
Fruit	1,220.3	1,060.4	9.8	2.4	141.6	6.1
Sugar	110.2	....	....	....	110.2	....
Total food consumed	4,316.3	2,353.4	126.5	462.8	1,344.6	29.0
Feces	102.9	....	26.9	28.8	36.8	10.4
Amount utilized	....	....	99.6	434.0	1,307.8	18.6
Per cent utilized	....	....	78.7	93.8	97.3	64.1
Experiment No. 63, subject R. L. S.:						
Blanc mange containing beef fat	2,141.4	1,077.1	42.8	391.9	616.7	12.9
Wheat biscuit	533.7	45.4	71.5	5.9	402.4	8.6
Fruit	1,250.2	1,086.4	10.0	2.5	145.0	6.3
Sugar	69.0	....	....	....	69.0	....
Total food consumed	3,994.3	2,208.9	124.3	400.3	1,233.1	27.8
Feces	116.1	....	28.7	44.2	32.4	10.9
Amount utilized	....	....	95.6	356.1	1,200.7	16.9
Per cent utilized	....	....	76.9	89.0	97.4	60.8

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[1] Diss., Army Med. Acad. St. Petersburg, 1890, p. 52.

[2] Loc. cit.

Data of digestion experiments with beef fat in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 69, subject R. L. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blanc mange containing beef fat	2,265.1	1,229.5	39.4	267.5	719.4	9.3
Wheat biscuit	661.1	56.2	88.6	7.3	498.5	10.5
Fruit	1,131.0	982.8	9.1	2.3	131.2	5.6
Sugar	77.3				77.3	
Total food consumed	4,134.5	2,268.5	137.1	277.1	1,426.4	25.4
Feces	137.0		35.1	39.9	49.3	12.7
Amount utilized			102.0	237.2	1,377.1	12.7
Per cent utilized			74.4	85.6	96.5	50.0
Experiment No. 70, subject I. D. B.:						
Blanc mange containing beef fat	2,275.2	1,235.0	39.6	268.7	722.6	9.3
Wheat biscuit	447.6	38.0	60.0	4.9	337.5	7.2
Fruit	1,229.0	1,068.0	9.8	2.5	142.6	6.1
Sugar	60.2				60.2	
Total food consumed	4,012.0	2,341.0	109.4	276.1	1,262.9	22.6
Feces	145.1		41.1	33.9	57.7	12.4
Amount utilized			68.3	242.2	1,205.2	10.2
Per cent utilized			62.4	87.7	95.4	45.1
Experiment No. 71, subject W. D.:						
Blanc mange containing beef fat	2,274.4	1,234.5	39.6	268.6	722.4	9.3
Wheat biscuit	495.5	42.1	66.4	5.5	373.6	7.9
Fruit	1,381.1	1,200.2	11.0	2.8	160.2	6.9
Sugar						
Total food consumed	4,151.0	2,476.8	117.0	276.9	1,256.2	24.1
Feces	91.5		21.5	24.4	35.9	9.7
Amount utilized			95.5	252.5	1,220.3	14.4
Per cent utilized			81.6	91.2	97.1	59.8
Experiment No. 72, subject E. M.:						
Blanc mange containing beef fat	2,462.4	1,336.6	42.8	290.8	782.1	10.1
Wheat biscuit	553.5	47.0	74.2	6.1	417.3	8.9
Fruit	1,528.6	1,328.4	12.2	3.1	177.3	7.6
Sugar	121.6				121.6	
Total food consumed	4,666.1	2,712.0	129.2	300.0	1,498.3	26.6
Feces	123.8		31.6	29.0	51.7	11.5
Amount utilized			97.6	271.0	1,446.6	15.1
Per cent utilized			75.5	90.3	96.5	56.8
Experiment No. 102, subject I. D. B.:						
Blanc mange containing beef fat	2,200.8	1,151.3	39.8	206.0	793.8	9.9
Wheat biscuit	557.7	47.4	74.8	6.1	420.5	8.9
Fruit	1,642.4	1,427.3	13.1	3.3	190.5	8.2
Sugar	44.4				44.4	
Total food consumed	4,445.3	2,626.0	127.7	215.4	1,449.2	27.0
Feces	109.9		26.6	27.4	45.5	10.4
Amount utilized			101.1	188.0	1,403.7	16.6
Per cent utilized			79.2	87.3	96.9	61.5
Experiment No. 103, subject W. D.:						
Blanc mange containing beef fat	1,145.0	598.9	20.7	107.2	413.0	5.2
Wheat biscuit	257.9	21.9	34.6	2.8	194.5	4.1
Fruit	1,331.2	1,156.8	10.6	2.7	154.4	6.7
Sugar	18.0				18.0	
Total food consumed	2,752.1	1,777.6	65.9	112.7	779.9	16.0
Feces	84.3		20.4	19.8	34.3	9.8
Amount utilized			45.5	92.9	745.6	6.2
Per cent utilized			69.0	82.4	95.6	38.8
Experiment No. 104, subject E. M.:						
Blanc mange containing beef fat	2,510.0	1,313.0	45.4	234.9	905.4	11.3
Wheat biscuit	328.9	28.0	44.0	3.6	248.0	5.3
Fruit	1,417.5	1,231.8	11.4	2.8	164.4	7.1
Sugar	156.2				156.2	
Total food consumed	4,412.6	2,572.8	100.8	241.3	1,474.0	23.7
Feces	114.2		28.5	30.2	44.2	11.3
Amount utilized			72.3	211.1	1,429.8	12.4
Per cent utilized			71.7	87.5	97.0	52.3
Average food consumed per subject per day	1,368.0	789.8	38.9	99.5	431.4	8.4

Summary of digestion experiments with beef fat in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
61	W. D	86.4	94.4	97.4	72.4
62	E. M	78.7	93.8	97.3	64.2
63	R. L. S	76.9	89.0	97.4	60.8
69	R. L. S	74.4	85.6	96.5	50.0
70	I. D. B	62.4	87.7	95.4	45.1
71	W. D	81.6	91.2	97.1	59.8
72	E. M	75.5	90.3	96.5	56.8
102	I. D. B	79.2	87.3	96.9	61.5
103	W. D	69.0	82.4	95.6	38.8
104	E. M	71.7	87.5	97.0	52.3
	Average	75.6	88.9	96.7	56.2

The average value, 88.9 per cent, is the digestibility of the fat content of the entire ration. However, this, it is believed, may be taken to represent the coefficient of digestibility of beef fat alone, inasmuch as this fat comprised over 97 per cent of the total fat content of the diet. The digestibility seemed to decrease with the decrease in the amount of fat consumed. One reason may be that the ether extract of the feces contains not only the undigested fat, but also some ether-soluble metabolic products. If it be assumed that the amount of metabolic products remained fairly constant in the different tests, there would obviously be a proportionately larger quantity present in the feces as the amount of fat consumed decreased.

MUTTON FAT.

That only small quantities of mutton fat are used in the United States for culinary purposes may be due partly to a smaller available supply, partly to its marked flavor, and partly to its relatively high melting point and corresponding hardness. The possibility of extending its use was considered in work undertaken with reference to the use of mutton in the diet.[1] One method of utilizing mutton fat in cooking consists in mixing small quantities after rendering with softer fats, such as lard. The resulting mixture is somewhat softer than the mutton fat and may be used for various household purposes. It is possible to make a savory fat by heating the mutton fat at a low temperature with an onion or sour apple and a little summer savory or ground thyme until the onion or apple is thoroughly brown. The peculiar flavor seems to be masked by this process, the savoriness being quite likely due to a solution in the fat of specific flavoring bodies in the seasoning herb and the browned fruit and vegetable.

Very little experimental work concerning the digestibility of mutton fat has been found. Grindley [2] in his studies of the effect of cooking upon the digestibility of meats included among others a leg of mutton, and found that the average digestibility of the fat in the ration was 98.5 per cent. His investigation was carried out, however, under conditions very different from those herein reported, as he included in the basal ration large amounts of meat.

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[1] U. S. Dept. Agr., Farmers' Bul. 526 (1913).

[2] Loc. cit.

A total of seven tests, each of three days' duration, was made with a diet containing a large quantity of mutton fat, and conditions parallel to those of the previous work were maintained throughout the experimental periods. The results are given below:

Data of digestion experiments with mutton fat in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 93, subject R. L. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blanc mange containing mutton fat	1,581.2	798.0	26.7	120.7	628.7	7.1
Wheat biscuit	467.1	39.7	62.6	5.1	352.2	7.5
Fruit	635.5	552.2	5.1	1.3	73.7	3.2
Sugar	49.2				49.2	
Total food consumed	2,733.0	1,389.9	94.4	127.1	1,103.8	17.8
Feces	100.7		24.4	34.2	32.8	9.2
Amount utilized			70.0	92.8	1,071.0	8.5
Per cent utilized			74.1	73.0	97.0	48.0
Experiment No. 94, subject I. D. B.:						
Blanc mange containing mutton fat	1,895.6	956.7	32.0	144.6	753.7	8.6
Wheat biscuit	592.4	50.3	79.4	6.5	446.7	9.5
Fruit	1,397.0	1,214.0	11.2	2.8	162.0	7.0
Sugar	80.2				80.2	
Total food consumed	3,965.2	2,221.0	122.6	153.9	1,442.6	25.1
Feces	108.8		27.5	29.8	42.0	9.4
Amount utilized			95.1	124.1	1,400.6	15.7
Per cent utilized			77.5	80.6	97.1	62.5
Experiment No. 95, subject W. D.:						
Blanc mange containing mutton fat	960.7	484.9	16.2	73.3	382.0	4.3
Wheat biscuit	262.0	22.3	35.1	2.9	197.5	4.2
Fruit	1,363.5	1,184.9	10.9	2.7	158.2	6.8
Sugar	32.3				32.3	
Total food consumed	2,618.5	1,692.1	62.2	78.9	770.0	15.3
Feces	79.6		18.7	21.7	30.1	9.0
Amount utilized			43.5	57.2	739.9	6.3
Per cent utilized			69.9	72.4	96.1	41.2
Experiment No. 96, subject E. M.:						
Blanc mange containing mutton fat	2,360.8	1,191.5	39.9	180.1	938.7	10.6
Wheat biscuit	366.4	31.1	49.1	4.0	276.3	5.9
Fruit	1,482.3	1,288.1	11.9	3.0	171.9	7.4
Sugar	82.2				82.2	
Total food consumed	4,291.7	2,510.7	100.9	187.1	1,469.1	23.9
Feces	132.6		35.4	33.7	51.0	12.5
Amount utilized			65.5	153.4	1,418.1	11.4
Per cent utilized			64.9	82.0	96.5	47.7
Experiment No. 131, subject D. G. G.:						
Blanc mange containing mutton fat	1,508.0	697.3	29.2	218.1	556.9	6.5
Wheat biscuit	765.0	65.0	102.5	8.4	576.8	12.3
Fruit	1,042.0	905.5	8.3	2.1	120.9	5.2
Sugar	122.0				122.0	
Total food consumed	3,437.0	1,667.8	140.0	228.6	1,376.6	24.0
Feces	122.6		32.0	26.9	52.0	11.7
Amount utilized			108.0	201.7	1,324.6	12.3
Per cent utilized			77.1	88.2	96.2	51.2

Data of digestion experiments with mutton fat in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 132, subject H. D. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blanc mange containing mutton fat	769.0	355.6	14.9	111.2	284.0	3.3
Wheat biscuit	483.0	41.1	64.7	5.3	364.2	7.7
Fruit	1,504.0	1,307.0	12.0	3.0	174.5	7.5
Sugar	183.0				183.0	
Total food consumed	2,939.0	1,703.7	91.6	119.5	1,005.7	18.5
Feces	84.5		22.6	19.2	33.8	9.0
Amount utilized			69.0	100.3	971.9	9.5
Per cent utilized			75.3	83.9	96.6	51.5
Experiment No. 133, subject R. L. S.:						
Blanc mange containing mutton fat	1,472.0	680.6	28.6	212.9	543.6	6.3
Wheat biscuit	552.0	46.9	4.0	6.1	416.2	8.8
Fruit	1,360.0	1,181.8	10.9	2.7	157.8	6.8
Sugar	63.0				63.0	
Total food consumed	3,447.0	1,909.3	113.5	221.7	1,180.6	21.9
Feces	110.5		28.7	36.7	32.3	12.8
Amount utilized			84.8	185.0	1,148.3	9.1
Per cent utilized			74.7	83.4	97.3	41.6
Average food consumed per subject per day	1,115.8	623.6	34.5	53.2	397.5	7.0

Summary of digestion experiments with mutton fat in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
93	R. L. S	74.1	73.0	97.0	48.0
94	I. D. B	77.5	80.6	97.1	62.5
95	W. D	69.9	72.4	96.1	41.2
96	E. M	64.9	82.0	96.5	47.7
131	D. G. G	77.1	88.2	96.2	51.2
132	H. D. G	75.3	83.9	96.6	51.5
133	R. L. S	74.7	83.4	97.3	41.6
	Average	73.4	80.5	96.7	49.1

The above data show that relatively small amounts of mutton fat were consumed, which was probably due for the most part to the pronounced flavor and to the well-known fact that mutton fat makes the mouth feel "furry," for it cools in the mouth and clings to the skin. This clinging effect is not noticeable with fats which remain fluid in the mouth.

The low values for availability of fat obtained in experiments Nos. 93 (R. L. S.) and 95 (W. D.), have lowered the general average. The digestibility of mutton fat would be increased to 83.6 per cent by disregarding these values; but, since the values for the digestibility of the protein and carbohydrate approximate the average, the evidence is thought insufficient to warrant such a correction. The average digestibility of mutton fat, therefore, is given as 80.5 per cent. This is materially lower than that of any of the other animal fats studied, though it is apparent that in comparison with many common foods the fat is sufficiently well assimilated to serve satisfactorily as a food material.

BUTTER.

Many investigators have studied the digestibility of butter under a wide variety of conditions, because of its very extensive use in countries where it is obtainable at relatively low prices. In a number of the earlier determinations the rations used consisted of only one food material in addition to the butter.

Rubner,[1] as a part of an extended series of experiments, determined the digestibility of a simple ration of butter and potatoes, and of one made up of green beans (540.2 grams) and butter (53.4 grams).[2] The coefficient of digestibility of fat in the first case was 96.3 per cent and in the second 91.5 per cent. In another test,[3] with a ration containing a considerably larger proportion of fat—240 grams of butter—daily, this fat was 97.3 per cent assimilated.

Atwater,[4] in studies made previous to his connection with the nutrition investigations of the Department of Agriculture, studied a simple diet of fish (1,584 grams) and butter (30.5 grams), and found that the fat had a coefficient of digestibility of 91 per cent.

A similar experiment by Malfatti [5] is reported in which polenta (a porridge made of Indian corn meal and butter), supplying 92.5 grams of fat per day, was used. The coefficient of digestibility of the fat of the corn meal alone was found to be 57.86 per cent, while the butter, which supplied by far the greater part of the fat content of the ration, was 97.7 per cent available.

The variation in digestibility as determined by the different investigators is doubtless due to a lack of uniformity of conditions under which the experiments were performed. The results of these early experiments, however, agree fairly well in showing that butter is very completely digested. In later experiments, which are also of interest, a more complex basal ration seems to have been used.

Mayer [6] studied the thoroughness of the digestion of butter by a 39-year-old man and a 9-year-old boy, who were given butter in a simple mixed diet. The average digestibility of butter as determined by three experimental periods, each of three days' duration, was for the man 98 per cent and for the boy 97 per cent.

Bertarelli [7] investigated the nutritive value of butter, using three healthy men as subjects for one experimental period each. He obtained 94 per cent as an average digestibility.

Huldgren and Landergren [8] used a simple basal ration of rye bread made of rye flour, water, and yeast and baked in hard, thin cakes.

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[1] Ztschr. Biol., 15 (1879), No. 1, pp. 136–147.

[2] Idem, 16 (1880), No. 1, p. 127.

[3] Idem, 15 (1879), No. 1, pp. 174–176.

[4] Idem, 24 (1887), No. 1, p. 16.

[5] Sitzber. K. Akad. Wiss. [Vienna], Math. Naturw. Kl., 90 (1884), III, No. 5, pp. 328–335.

[6] Landw. Vers. Stat., 29 (1883), pp. 215–232.

[7] Riv. Ig. e. Sanit. Pub., 9 (1898), Nos. 14, pp. 538–545; 15, pp. 570–579.

[8] Skand. Arch. Physiol., 2 (1890), No. 4–5, pp. 373–393.

The experimenters themselves were the subjects, and found that 95.43 per cent of butter fat was digested.

Lührig[1] found that butter in a basal ration of meat, bread, and vegetables was 96 per cent digested by a healthy man 29 years old. In a later paper[2] he reports a digestibility of 97 per cent.

Another series of experiments in which the experimenters were subjects was conducted by Wibbens and Huizenga,[3] who compared butter and sana (a butter substitute which contained no milk fat). A simple mixed diet was eaten during periods of three days' duration. For one subject the fat digestibilities were: Butter, 97.33 per cent; sana, 95.3 per cent; for the other subject, butter, 96.5; sana, 73.79 per cent.

A much longer experimental period, one of 28 days' duration, divided into a fore period of 7 days, a period of 14 days on the special diet studied, and an after period of 7 days, was preferred by Von Gerlach.[4] He determined the thoroughness of digestion of butter and of a commercial product called "sanella" (of vegetable origin), when the basal ration consisted of rice, zweiback, and oatmeal. Both fats were 97 per cent digested.

Flurin[5] and Levites[5] have found that butter was 96 per cent assimilated.

Investigating the digestibility of the protein, fat, and carbohydrate contents of the ordinary mixed diet, Atwater[6] used varying amounts of butter (40 grams to 343 grams per man per day) in the ration, and concluded that for three different subjects in 21 experiments the fat of the diet was 95.9 per cent available to the body.

It is difficult to compare the results of all these investigations, since the experimental conditions were not of similar nature. In the main, however, they show that butter fat is very well assimilated.

In the eight tests recently conducted in this laboratory conditions were more nearly uniform, as the butter was added to the same simple mixed diet and eaten by the same subjects who participated in the other experiments. The results which were obtained follow.

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[1] Ztschr. Untersuch. Nahr. u. Genussmtl., 2 (1899), No. 6, pp. 484–506.

[2] Idem, No. 10, pp. 769–783.

[3] Pflüger's Arch. Physiol., 83 (1901), No. 10–12, pp. 609–618.

[4] Ztschr. Phys. u. Diätet: Ther., 12 (1908–9), No. 2, pp. 102–110.

[5] Loc. cit.

[6] Connecticut Storrs Sta. Rpt. 1901, p. 235.

Data of digestion experiments with butter in a simple mixed diet.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 85, subject R. L. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blanc mange containing butter	1,707.0	757.7	28.9	314.9	585.2	20.3
Wheat biscuit	403.8	34.3	54.1	4.4	304.5	6.5
Fruit	909.9	790.7	7.3	1.8	105.6	4.5
Sugar	51.0				51.0	
Total food consumed	3,071.7	1,582.7	90.3	321.1	1,046.3	31.3
Feces	73.9		19.6	22.6	24.2	7.5
Amount utilized			70.7	298.5	1,022.1	23.8
Per cent utilized			78.3	93.0	97.7	76.0
Experiment No. 86, subject I. D. B.:						
Blanc mange containing butter	1,911.7	848.6	32.3	352.7	655.3	22.8
Wheat biscuit	398.6	33.9	53.4	4.4	300.5	6.4
Fruit	1,122.0	975.0	9.0	2.2	130.2	5.6
Sugar	84.0				84.0	
Total food consumed	3,516.3	1,857.5	94.7	359.3	1,170.0	34.8
Feces	114.9		34.8	16.8	51.9	11.4
Amount utilized			59.9	342.5	1,118.1	23.4
Per cent utilized			63.3	95.3	95.6	67.2
Experiment No. 87, subject W. D.:						
Blanc mange containing butter	1,008.5	447.7	17.0	186.1	345.7	12.0
Wheat biscuit	340.5	28.9	45.8	3.7	256.7	5.4
Fruit	1,201.6	1,044.2	9.6	2.4	139.4	6.0
Sugar						
Total food consumed	2,550.6	1,520.8	72.4	192.2	741.8	23.4
Feces	83.2		21.7	16.9	34.9	9.7
Amount utilized			50.7	175.3	706.9	13.7
Per cent utilized			70.0	91.2	95.3	58.5
Experiment No. 88, subject E. M.:						
Blanc mange containing butter	2,067.3	917.7	34.9	381.4	708.7	24.6
Wheat biscuit	329.7	28.0	44.2	3.6	248.6	5.3
Fruit	1,214.2	1,055.1	9.7	2.4	140.8	6.1
Sugar	94.9				94.9	
Total food consumed	3,706.1	2,000.8	88.8	387.4	1,193.0	36.0
Feces	96.7		29.9	14.3	42.5	10.1
Amount utilized			58.9	373.1	1,150.5	25.9
Per cent utilized			66.3	96.3	96.4	71.9
Experiment No. 117, subject R. L. S.:						
Blanc mange containing butter	1,234.0	574.9	20.9	195.8	428.1	14.3
Wheat biscuit	485.0	41.2	5.0	5.3	365.7	7.8
Fruit	794.0	670.0	6.3	1.6	92.1	4.0
Sugar	44.0				44.0	
Total food consumed	2,557.0	1,306.1	92.2	202.7	929.9	26.1
Feces	94.7		30.5	18.5	33.0	12.7
Amount utilized			61.7	184.2	896.9	13.4
Per cent utilized			66.9	90.9	96.5	51.3
Experiment No. 118, subject I. D. B.:						
Blanc mange containing butter	2,017.0	939.7	34.1	320.1	699.7	23.4
Wheat biscuit	497.0	42.2	66.6	5.5	374.7	8.0
Fruit	948.0	823.8	7.6	1.9	110.0	4.7
Sugar	92.0				92.0	
Total food consumed	3,554.0	1,805.7	108.3	327.5	1,276.4	36.1
Feces	103.7		27.9	17.4	47.8	10.5
Amount utilized			80.4	310.1	1,228.6	25.6
Per cent utilized			74.2	94.7	96.3	70.9
Experiment No. 119, subject W. D.:						
Blanc mange containing butter	1,501.0	699.3	25.4	238.2	520.7	17.4
Wheat biscuit	354.0	30.1	47.4	3.9	266.9	5.7
Fruit	1,143.0	993.3	9.1	2.3	132.6	5.7
Sugar						
Total food consumed	2,998.0	1,722.7	81.9	244.4	920.2	28.8
Feces	96.0		21.9	15.3	35.0	13.8
Amount utilized			60.0	229.1	885.2	15.0
Per cent utilized			73.3	93.7	96.2	52.1

Data of digestion experiments with butter in a simple mixed diet—Continued.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 120, subject E. M.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blanc mange containing butter	2,198.0	1,024.0	37.2	348.8	762.5	25.5
Wheat biscuit	294.0	25.0	39.4	3.2	221.7	4.7
Fruit	1,194.0	1,037.6	9.5	2.4	138.5	6.0
Sugar	105.0				105.0	
Total food consumed	3,791.0	2,086.6	86.1	354.4	1,227.7	36.2
Feces	84.2		24.1	15.2	34.8	10.2
Amount utilized			62.0	339.2	1,192.9	26.0
Per cent utilized			72.0	95.7	97.2	71.9
Average food consumed per subject per day.	1,072.7	578.7	29,8	99.5	354.4	10.5

Summary of digestion experiments with butter in a simple mixed diet.

Experiment No.	Subject.	Protein.	Fat.	Carbohydrates.	Ash.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
85	R. L. S	78.3	93.0	97.7	76.0
86	I. D. B	63.3	95.3	95.6	67.2
87	W. D	70.0	91.2	95.3	58.5
88	E. M	66.3	96.3	96.4	71.9
117	R. L. S	66.9	90.9	96.5	51.3
118	I. D. B	74.2	94.7	96.3	70.9
119	W. D	73.3	93.7	96.2	52.1
120	E. M	72.0	95.7	97.2	71.9
	Average	70.5	93.9	96.4	65.0

Having an average digestibility of 93.9 per cent, butter fat may be considered more completely assimilated than any of the other animal fats considered in this report. Though a reasonable allowance of butter is 3 ounces, or 85 grams, per man per day, the experiments as a whole emphasize a fact of common experience, namely, that somewhat larger quantities of butter (100 grams per day at least) may be eaten in ordinary circumstances and utilized without any noticeable physiological disturbance.

ALLOWANCE FOR METABOLIC FAT.

The coefficients of digestibility given in the preceding discussion are gross rather than net values. They have been derived in the customary way by analyzing the food eaten and the feces excreted during an experimental period to determine especially what proportion of the ingested fat was available for the maintenance of the needs of the body. For this purpose the total ether extract of the feces has been taken to represent the actual quantity of undigested fat—the unavailable residual of the fat eaten during the experimental period. That this assumption is not strictly true is apparent from a study of the composition of the feces. It is well known that the feces contain not only undigested residues of food, but certain other waste materials, which are ordinarily designated as metabolic products. These include residues of bacteria, digestive juices, internal secretions, and epithelial cells of the stomach and intestines. Some of these products of the body metabolism are soluble in ether and therefore occur in the ether extract of the feces, together with the fat actually unavailable. Moreover, these metabolic products are not derived necessarily from the fat under consideration, but may be formed from protein and carbohydrate as well, and probably are produced partly from food eaten prior to the beginning of the experimental period.

To determine either the amount or the percentage of fat actually unutilized as distinguished from the total fecal fat (often called "undigested fat"), allowance must be made for fat in the fecal metabolic products. The method adopted is not a direct one, since it is impractical to make the separation quantitatively, but is based on the assumption that the quantity and quality of metabolic products found depend on the nature and the amount of ingested food—that the average percentage of metabolic products found in the ether extract when the basal ration alone is eaten will be approximately equal to that when the basal ration together with added fat is consumed.

Four experiments are herein reported with the basal ration without added fat. The procedure was in no way different from that employed in those tests in which large amounts of added fat were eaten, the bulk of food in each series of experiments being approximately equal. The results of these tests are given below and furnish a basis for calculating the necessary allowance for the metabolic products contained in the ether extract of the feces.

Data of digestion experiments with basal ration.

	Weight.	Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 266, subject H. F. B.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blanc mange without added fat	2,307.0	1,296.8	45.4	14.5	939.0	11.3
Wheat biscuit	592.0	47.4	65.1	17.8	449.9	11.8
Fruit	1,392.0	1,211.0	13.9		167.1	
Sugar	208.0				208.0	
Total food consumed	4,499.0	2,555.2	124.4	32.3	1,764.0	23.1
Feces	136.0		38.9	11.8	73.4	11.9
Amount utilized			85.5	20.5	1,690.6	11.2
Per cent utilized			68.7	63.5	95.8	48.5
Experiment No. 267, subject D. G. G.:						
Blanc mange without added fat	1,922.0	1,080.4	37.9	12.1	782.2	9.4
Wheat biscuit	335.0	26.8	36.9	10.0	254.6	6.7
Fruit	1,027.0	893.5	10.3		123.2	
Sugar	149.0				149.0	
Total food consumed	3,433.0	2,000.7	85.1	22.1	1,309.0	16.1
Feces	87.0		28.6	8.3	42.2	7.9
Amount utilized			56.5	13.8	1,266.8	8.2
Per cent utilized			66.4	62.4	96.8	50.9

Data of digestion experiments with basal ration—Continued.

	Weight.	Water.	Protein.	Fat.	Carbo-hydrates.	Ash.
Experiment No. 268, subject R. L. S.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blanc mange without added fat	2,054.0	1,154.5	40.5	12.9	836.0	10.1
Wheat biscuit	424.0	33.9	46.7	12.7	322.2	8.5
Fruit	1,225.0	1,065.8	12.2		147.0	
Sugar	86.0				86.0	
Total food consumed	3,789.0	2,254.2	99.4	25.6	1,391.2	18.6
Feces	93.0		28.8	16.8	38.5	8.9
Amount utilized			70.6	8.8	1,352.7	9.7
Per cent utilized			71.0	34.4	97.2	52.2
Experiment No. 269, subject O. E. S.:						
Blanc mange, without added fat	2,222.0	1,249.0	43.8	14.0	904.3	10.9
Wheat biscuit	365.0	29.2	40.1	11.0	277.4	7.3
Fruit	636.0	553.3	6.4		76.3	
Sugar	226.0				226.0	
Total food consumed	3,449.0	1,831.5	90.3	25.0	1,484.0	18.2
Feces	110.0		33.5	11.7	55.2	9.6
Amount utilized			56.8	13.3	1,428.8	8.6
Per cent utilized			62.9	53.2	96.3	47.3
Average food consumed per subject per day	1,264.1	720.1	33.3	8.8	495.7	6.3

Samples of the blanc mange (containing only small amounts of milk fat) and of the wheat biscuit (containing cereal fat) were analyzed, and in the calculation it has been assumed on the basis of a previous investigation[1] that 5 per cent of the milk fat and 10 per cent of the wheat fat are undigested. The difference between the total ether extract of the feces and the amount of unutilized fat (5 per cent of milk fat and 10 per cent of wheat fat) is taken to be the amount of metabolic products occurring in the ether extract. In the following table are given the necessary data from the four basal ration experiments for obtaining the average percentage of metabolic products occurring in the ether extract of the feces. This value is a percentage of the weight of water-free feces.

Allowance for metabolic products.

	Experiment No. 266, subject H. F. B.	Experiment No. 267, subject D. G. G.	Experiment No. 268, subject R. L. S.	Experiment No. 269, subject O. E. S.
	Grams.	*Grams.*	*Grams.*	*Grams.*
Weight of water-free feces	136.0	87.0	93.0	110.0
Milk fat in blanc mange	14.5	12.1	12.9	14.0
Vegetable fat in wheat biscuit	17.8	10.0	12.7	11.0
Total ether extract of feces	11.8	8.3	16.8	11.7
Undigested milk fat in feces (estimated)	.7	.6	.6	.7
Undigested wheat fat in feces (estimated)	1.8	1.0	1.3	1.1
Metabolic products in ether extract of feces	9.3	6.7	14.9	9.9
Per cent of water-free feces computed as metabolic products in ether extract of feces	6.84	7.70	16.02	9.00

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[1] Connecticut Storrs. Sta. Rpt. 1899, p. 104.

The average amount of the water-free feces occurring as metabolic products in the ether extract is, accordingly, 9.89 per cent. The method of making the allowance is indicated by the following equations:

9.89 × (weight of water-free feces) = metabolic products.

(Total ether extract) − (metabolic products) = unutilized fat.

(Utilized fat) ÷ (total fat eaten) = per cent of digestibility.

Applying these equations to the values which express the comparative digestibilities of the fats studied, the coefficients of digestibility are increased to 97.3 per cent for lard, 93.1 per cent for beef fat, 87.6 per cent for mutton fat, and 97.1 per cent for butter.

Should the percentage of metabolic products be based on the total weight of food as eaten, rather than on the weight of water-free feces, this value is found to be 0.27 per cent. The corresponding availabilities of the four fats, in the order studied, then become 97.3 per cent, 93.0 per cent, 86.8 per cent, and 96.9 per cent. That these values should agree so closely with those based on the weight of water-free feces is in accordance with the theory proposed by Prausnitz,[1] that the amount of metabolic products occurring in the feces is directly dependent upon the character and quantity of the ingested food—that food materials do not leave residues for feces, but produce feces composed principally of metabolic products.

GENERAL DISCUSSION.

All the fats included in this series of experiments were well assimilated, the coefficients of digestibility ranging from 97 per cent for butter to 88 per cent for mutton fat. The average amounts of fat eaten per subject per day during these experiments were 90 grams of lard, 100 grams of beef fat, 53 grams of mutton fat, and 100 grams of butter.

The average amount of protein consumed daily by the subjects was somewhat lower than that specified in dietary standards, but it was only limited by personal choice, as the subjects were permitted to eat as much of the wheat biscuit as they desired. Moreover, since only the fat portion of the diet was under consideration, it was not considered essential to maintain any special nitrogen level.

The values for the digestibility of the carbohydrate content of the diets were 96, 97, 97, and 96 per cent, for all practical purposes identical with its digestibility in the ordinary mixed diet, for which the average value is 97 per cent.[2]

The average energy value available per man per day as calculated by the usual factors and the coefficients of availability found in the digestion experiments was 2,235 calories for the lard, 2,730 calories for the beef fat, 2,145 calories for the mutton fat, and 2,420 calories for the butter diet. These energy quantities would be insufficient for severe muscular activity, but should meet the needs of those following sedentary occupations.

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[1] Ztschr. Biol., 30 (1894), No. 12, p. 335.

[2] Connecticut Storrs Sta. Rpt. 1901, p. 245.

It is interesting to know whether or not the presence in the diet of the different fats in considerable quantity affects the digestibility of the other constituents and the coefficient of availability of the ration as a whole. It has been shown by work previously reported[1] that the total available energy and the "coefficient of availability of energy" can be calculated with reasonable accuracy. The average coefficients of availability of energy for the rations as calculated were 93.0 per cent, 92.7 per cent, 91.5 per cent, and 93.9 per cent for the diets containing lard, beef fat, mutton fat, and butter, respectively. These values agree with one another closely and are somewhat higher than the value 91 per cent which has been found to represent the coefficient of availability of energy of the ordinary mixed diet.[2] It is reasonable to conclude, therefore, that the different fats did not exercise any unusual effect upon the digestibility of the other constituents of the rations.

The statement has frequently been made that the coefficients of digestibility of fats are directly related to the corresponding melting points. The melting points of samples of the fats studied or of samples of fats similarly prepared are reported in the table below together with a compilation of values[3] determined by several investigators giving, presumably, the average range found in samples fairly true to name. The variation in the melting points of different samples of the same fat is consistent with the view that the melting points differ with the part of the body in which the fat is found and also with the animal from which it is taken.

Comparison of digestibility and melting point.

Fat studied.	Coefficient of digestibility.		Melting point.	
	Determined.	With allowance for metabolic products.	Authors' determinations.	Compiled average values.[1]
	Per cent.	*Per cent.*	*Degrees C.*	*Degrees C.*
Butter fat	94	97	32.0	28–36
Lard	94	97	35.0	30–44
Beef fat	89	93	45.0	42–50
Mutton fat	80	88	50.0	47–49

[1] Allen's Commercial Organic Analysis. Philadelphia: Blakiston's Son & Co., 1910, 4. ed., vol. 2, p. 72.

It seems fair to conclude that of those tested the fats of low melting points are capable of more complete assimilation than those which have a high melting point.

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[1] Connecticut Storrs Sta. Rpt. 1899, p. 104.

[2] U. S. Dept. Agr., Expt. Sta. Bul. 136 (1903), p. 113.

[3] Allen's Commercial Organic Analysis. Philadelphia: Blakiston's Son & Co., 1910, 4. ed., vol. 2, p. 72.

Many more culinary and table fats are being studied and it is expected that it will be possible to judge whether this phenomenon is merely applicable to the instances cited or whether in general the coefficient of digestibility decreases as the melting point increases.

In the beef-fat experiments, in which approximately 140 grams of fat were consumed per day, the subjects reported a tendency toward a laxative condition, which was not noted when the amount of fat consumed was decreased. As no such condition resulted from eating the other fats, it would seem from the information at hand that the limit of tolerance for these may have been higher than for beef fat. Information in this regard is of considerable interest especially when it is desirable to make use of a diet containing an excessive amount of fat.

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